An Observational Study on Information Flow during Nurses' Shift Change

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ABSTRACT
We present an observational study that was conducted to guide the design and development of technologies to support information flow during nurses' shift change in a hospital ward. Our goal is to find out how the complex information sharing processes during nurses' brief shift change unfold in a hospital setting. Our study shows the multitude of information media that nurses access during the parallel processes of information assembly and disassembly: digital, paper-based, displayed and verbal media. An initial analysis reveals how the common information spaces, where information media are positioned and accessible by all participants, are actively used and how they interact with the personal information spaces ephemerally constructed by the participants. Several types of information are consistently transposed from the common information spaces to the personal information space including: demographics, historical data, reminders and to-dos, alerts, prompts, scheduling and reporting information. Information types are often enhanced with a variety of visual cues to help nurses carry out their tasks.

Author Keywords
Shift change, information flow, observational study, nursing, common information space, personal information space, information assembly, information disassembly.

ACM Classification Keywords
H.0 [Information systems]; K.4.3 [Organizational Impacts]: Computer-supported collaborative work

INTRODUCTION
Communication within medical environments is ubiquitous and accounts for a substantial part of healthcare practitioners' daily routines, encompassing interactions in varying contexts and information sharing across temporal and spatial dimensions [3,4,6,14]. As we move into the 21st century, medical care is making increasing use of technology and medical records are now largely digital. However, the handling of medical information is often still a mixture of mental recollection, handwritten notes, large charts on white boards, verbal reports, digital records and printed records. In this period of shifting media usage, the task of information exchange that nurses are faced with during shift change could be facilitated. This is in part due to the fact that the hardware technology in use was probably initially designed for office use, with only the software specifically designed for hospital use.

Our long range research goals are to address the question of how to design technology that can better support the task of information exchange and fit more seamlessly and less obtrusively into the working environment. We have conducted an observational study to investigate how tasks are currently performed, in order to acquire insights into how technology should be designed to support these activities [14,16]. We observe how nurses acquire and dispense information, what information media and what information artifacts are involved, how the information seeking and distribution processes are carried out, and how and what information is transposed from a multitude of information artifacts to personal artifacts.

Our study focuses on the basic practices of information flow during nurses' shift change and on how technologies impact the efficiency and effectiveness of the information flow processes. Information flow is used here to refer to the manner in which communication of information takes place across shifts. We chose to study nurses instead of general clinical shift work, as nurses are at the frontline of patient care, spending most of their working hours with patients. The information they obtain during shift change directly impacts the quality of care provided to patients.

BACKGROUND
Clinical handover, a fundamental practice in medical settings, is used to transfer medical information across shifts and is an essential aspect of health care delivery [8,15]. Shift work relies heavily on effective information transfer to ensure patient safety. The information communicated during shift change provides incoming nurses with a "the picture of the ward" [3,10]; it thereby influences the delivery of care for the entire shift and the

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overall quality of patient care. Although nurses change in temporally overlapping shifts, they may not occupy the same space in this overlap causing both spatial and temporal separation. This separation can complicate the shift-change process as the separation prevents them from discussing and clarifying the interpretation of information in transit [1,4,6].

A literature survey [11] showed that *"ineffective handover can lead to wrong treatment, delays in medical diagnosis, life threatening adverse events, patient complaints, increased health care expenditure, increased hospital length of stay and a range of other effects that impact on the health system"*. Communication failure and missing information during shift change have also been found to be contributing factors in many clinical mishaps [8,11,15].

Popular handover methods used during shift change include patient bedside handover, audio-taped handover and handover conference [8,15]. Handover, in whatever mode, provides the opportunity for nurses in consecutive shifts to communicate important medical information, such as a patient's diagnosis, vital signs, diagnostic tests and restrictions, and to ensure the continuity of patient care [8,11,15]. Most past studies on medical handovers focus on the benefits and drawbacks of a particular handover practice and investigate if one handover style should be replaced by another [8,15].

Since the information required for accomplishing cooperative work is often spatially distributed (both in general and in the hospital ward of our case study), it is important to ensure that information is actively placed and assigned meanings in a common information space where information can be retrieved, interpreted and manipulated for accomplishing and continuing with the cooperative work. A common information space (CIS) "encompasses the artifacts that are accessible to a cooperative ensemble *as well as* the meaning attributed to these artifacts by the actors" [14]. Bannon and Bodker (1997) also pointed out that a CIS is characterized by the interplay between its openness and malleability of its information as well as its need for organization of various forms to allow for translation and portability across communities. It is probable that the nature of information organization relates closely to the degree of distribution among collaborators. For instance, the CISs constructed for a team of mostly co-present collaborators (both temporally and spatially) often provide for a high degree of openness and malleability of information so that interpretations of information can be easily clarified. In other situations, when collaborators are operating at arm's length, the CISs are constructed across time and space boundaries [1,6,14], resulting in reduced openness (closure) and malleability of information such that the collaborators cannot negotiate the interpretations of information. Thus the structure of a CIS is often characterized by whether the team is distributed or collocated either temporally or spatially.

Moreover, an information space is often interpreted in situated perspectives across different workgroups so that the space can be flexibly and adaptively used for their own purposes [9]. For instance, a patient chart is used by physicians, nurses, and a variety of ancillary professionals for different purposes. Physicians use the chart predominately to document patient treatment and progress and to give instructions to nurses. Nurses look for instructions in a patient chart and to communicate with physicians. Therefore, with the same coordinating artifact, different workgroups record and retrieve information with different horizons of meaning and relevance.

OBSERVATIONAL STUDY

Our research interest is in the specific communication practices that compose the fundamental and important information flow during nurses' daily shift change. In order to provide the best possible healthcare to patients, nurses working in different shifts must work collaboratively to ensure that all patient care tasks are carried out properly. This is also why efficient and accurate flow of information between nurses in consecutive shifts is so important.

We employ the concept of a *common information space* (CIS) in our analysis to explore how a common understanding of a work situation and its coordination is achieved through a combination of information, its representations and interpretations [1,14]. For the purpose of our analysis, we regard a *personal information space* (PIS) as an information space that consists of both artifacts and assigned meaning similar to the CIS but is constructed, interpreted and manipulated by only one person. The PIS described here is not the same as the personal or local information space described by Schmidt and Bannon [14], which refers to the local mindset within an individual or some common beliefs among a group of people.

METHODOLOGY

We performed an observational study in a local hospital ward, the Ward of the 21st Century (W21C), to acquire a thorough understanding of the information media involved, how information is assembled by incoming nurses, what information types are extracted from these media and transformed into personal notes as well as how information is disseminated by outgoing nurses during shift change.

For clarity, we use "ancillary professionals" to stand for a variety of allied health professional groups such as physiotherapists, respiratory therapists, occupational therapists, speech therapists, and social workers. Also, we use fabricated names in the extracts for illustration.

Participants

Participants in our study were 2 patient care managers, 37 registered nurses and 3 undergraduate nursing students, all of whom were employees of the ward. We use the term "nurses" for registered nurses and student nurses hereafter for simplicity. Five of the nurses were male and the patient care managers and students were all female.

Setting

The W21C, where this study was performed, is a uniquely designed hospital ward with two principal goals: *"to create a novel hospital-based physical infrastructure that would provide opportunities for creating health care solutions in the broad spectrum of internal medicine… and to create a novel research environment around this new infrastructure"* [5].

Figure 1 shows the layout of the ward. While some shift change activities such as face-to-face communication between nurses of consecutive shifts may occur inside patient rooms or along corridors of the three wings in the ward (top, Figure 1), most of the shift change activities take place in and around the nurses' station, the shift change room and the computer terminals (bottom, Figure 1).

Procedure

To obtain a thorough understanding of the current information flow practices, a minimally-intrusive observational study of information flow during shift change in the ward was conducted, combined with the shadowing of nurses during shift change (without entering patient rooms) and informal interviews. Twenty-five observation sessions were conducted during all nursing shifts, i.e., day/evening, evening/night and night/day shift changes. Observational data were recorded with pen and paper. In addition to the observational notes, we collected copies of the incoming and outgoing nurses' paper artifacts, specifically personal notes and/or *patient care summaries*, which were created and/or annotated at the beginning of their shift and used to assist their work during their shift. We also asked them, whenever possible, for descriptions and explanations of the personal notes and/or the patient care summaries and how they used them during their shift.

Observations were conducted at/during the following locations and activities.

- Inside the shift change room: we observed outgoing nurses updating the large whiteboards and incoming nurses preparing for their shift.
- In and around the nurses' station: we observed outgoing nurses performing verbal reporting to the charge nurse.
- Near the computer terminals: we observed nurses performing digital charting of patient information.
- Shadowing nurses: we shadowed incoming nurses to acquire a better picture of how they prepare for their shift by accessing a diversity of spatially distributed information artifacts.
- Charge nurse handover: we observed how an outgoing charge nurse reports to the incoming charge nurse.

Inside the Shift Change Room

Observations were made inside the shift change room, which is access-controlled for only authorized personnel such as doctors and nurses, to look for what actions

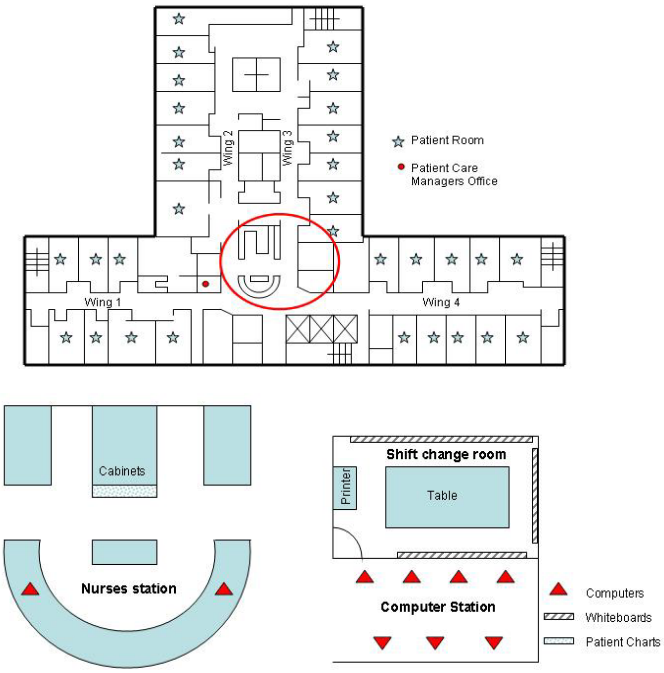

Figure 1: (top) Floor plan of the ward; (bottom) Layout showing the nursing station, shift change room and computer station – area circled in the floor plan above.

participants undertook to prepare for their shift which were mainly: preparation of personal notes and/or an annotated patient care summary, and obtaining the latest patient information from the large whiteboards which had been updated by the nurses working in the previous shift. We also observed outgoing nurses updating whiteboards inside the shift change room and what physical artifacts they used during the posting.

Charge reporting

We observed outgoing nurses report to the charge nurse. We wanted to see if and what physical artifacts were used when they were making the verbal reports. Since we tried to keep the observation minimally intrusive, it was often difficult to capture meaningful and complete report contents. However, we tried to follow up with short interviews with the outgoing nurses and sometimes the charge nurse as to what types of information were being reported and how charge nurses used their own copy of the patient list which is specifically used by charge nurses for three shifts in a day.

Computer Charting

We observed outgoing nurses charting patient information at computer terminals. The goal was to find out the types of information being charted and the time taken to chart.

Shadowing Incoming Nurses

We observed incoming nurses preparing for their shift to find out the information flow routines and the order in which nurses undertook these routines during shift change.

Charge Nurse Handover

We observed the meeting between the incoming and outgoing charge nurses. The goal was to get a better understanding of what kind of information was communicated and what intermediary artifacts were used for the information flow.

In addition to observations as described above, we also obtained samples of the participants' personal notes and/or their annotated patient care summaries for our analysis.

RESULTS

We analyzed the observational data first by listing the actions and then ordering them as they were performed by each participant when preparing personal notes inside the shift change room. We then tabulated the data to look for similarities and differences among the participants.

We analyzed the personal notes and the annotated patient care summaries using an open coding technique to identify the categories of information that were extracted from various information media and how the information helped them carry out the tasks during their shift. The classification was then verified by our participant nurses who agreed that they correctly represent the information required to carry out their tasks and their intended use.

We first present some general observations. We then describe the types of information media that nurses access during shift change, the information content and function types that we have identified from the personal artifacts collected during the study, the types of information spaces (CISs and PISs) that we use to describe and analyze our observations and the types of information processes that were identified in our study. Finally we describe the information processes we observed noting the assembly and disassembly of information and the temporal coordination as conducted.

General Observations

We observed that incoming nurses moved around the ward to access, gather, interpret, negotiate and manipulate the information placed in a multitude of information artifacts constructed by nurses in previous shifts and professionals in other disciplines such as physicians and ancillary professionals. They created personal notes with the information they gathered, assigned meaning, negotiated and maneuvered from the information artifacts to guide, remind, prompt, schedule and adapt for use in their shift work. Finally at the end of a work shift, they became the outgoing nurses, who then contextualized, organized, and transposed information from their personal notes back to the information artifacts from which they had foraged for information at the beginning of their work shift.

Observations were conducted on a total of 40 incoming nurses (37 nurses and 3 student nurses) inside the shift change room to investigate what and how they prepare for their shift. We found that all the nurses we observed prepared some form of personal notes, either on a separate sheet of paper and/or as annotations on the printed patient care summary. Specifically, 75% wrote down notes on a separate note-sheet and 25% used the annotated patient care summary as personal notes. For those using a separate note-sheet, all assigned specific locations for specific types of information (i.e. designated spatial arrangement), 40% highlighted information they deemed important or needed attention during their shift, and 10% color-coded important information. We also found the majority (83%) wrote down the notes from the previous shift, either from the large whiteboard inside the shift change room or from the verbal report by the outgoing nurse. On the same note-sheet, 10% wrote that as annotations on the patient care summary and the remaining 7% relied on their memory.

While shift change should be completed officially within 15 minutes (e.g., evening shift 3:00-3:15pm), our observations indicated that it took much longer. To illustrate, several incoming nurses had been inside the shift change room preparing for their shift since 2:30pm, and suddenly a nurse commented, "Why is Helen not here yet?" The researcher looked at her watch and it was 2:45pm, so she questioned, "Doesn't shift change start at 3 till 3:15 (pm)?" All the nurses there chuckled and one said, "yeah, not if you want to be prepared for your work!" All others agreed.

We observed that incoming nurses require typically between 30 to 45 minutes, depending on if they are assigned new patients and if there are complicated cases in their assignments, to complete assembling the information that they will need during shift change.

There are several important categories under which we will discuss our observations. These are the types of information media, information contents and functions, information spaces, and information processes through which the nurses interact with these media, content and spaces. While we feel that it is the processes that are of the most interest in our observations, we will discus them last since these processes use the media, content and spaces.

Information Media Types

By shadowing nurses, we identified the diversity of information media through which information is shared. As asynchronous communication is predominant during shift change in this hospital ward, correct interpretation of the information placed in the common information spaces is crucial for the accurate information flow during shift change. In the W21C, information is distributed over paper-based, verbal, displayed and digital media. Specifically, these information sources are: (1) digital patient records; (2) paper-based patient care summaries, patient charts containing laboratory and diagnostic results and written consults by physicians; (3) displayed patient information on large whiteboards and notices addressing the nursing staff; and (4) verbal handover from nurses of previous shifts and instructions from the charge nurse.

***Digital Media*:** Patients' medical information is largely digitized in the local health region. Most information concerning a patient's medical history and treatments can be found in the *electronic health record* (EHR) including laboratory and diagnostic test results. Some information such as consults by physicians and ancillary professionals can only be found in the paper-based patient charts.

***Paper-based Media*:** *Patient care summary* is an abbreviated form of the EHR, which provides important and relatively recent medical information of a patient that the caring nurse needs to know in order to provide quality healthcare. For example, it includes a patient's diagnosis, allergies, a brief illness trajectory, nurse to nurse communications, nursing orders, diet, scheduled medications, medications upon request, laboratory orders and instructions and consults by ancillary professionals. Each patient's care summary usually consists of several printed pages. At the beginning of each shift, fresh copies of patient care summary containing important patient information will be printed inside the shift change room. Despite the fact that these patient care summaries are printed as close to the beginning of each shift, information contained in these summaries are typically not up-to-date. To illustrate, summaries are printed out around 2:30pm for the nurses working evening shift, but outgoing nurses often have not updated the EHR before 2:30pm especially in situations where changes are expected in the patient's conditions near the end of their shift. Therefore, updated information has to be obtained through other channels.

For each patient admitted to the ward a *Patient Chart* is opened. This is a big binder filed with all kinds of paper documents pertinent to the patient. The chart contains written consults, e.g., consults from Emergency Room and physicians, multidisciplinary progress report (MPR) by ancillary professionals as well as communication between nurses and physicians such as orders given to nurses on duty. The patient charts are indexed by room number placed in a cabinet located at the back of the nursing station (Bottom of Figure 1, labeled "Cabinet").

***Displayed Media*:** *Large whiteboards* are inside the access-controlled shift change room and are in the public area facing the nursing station near the entrance to the ward. Whiteboards in the shift change room are divided into columns and rows. Columns list the room/bed number, patient's last name, followed by reports from the day-shift, the evening-shift and the night-shift nurses in separate columns and often in different colors. Shift reports posted on the whiteboards usually contain shift-specific activities and patient information that the outgoing nurse has performed and gathered. On the other hand, whiteboards placed in the public area are assignment boards showing the nurse assignments as well as doctor assignments. Doctors of different specialties and ranks are shown in varying colors. This information is particularly important for locating specific personnel when nurses need to seek professional opinions and clarifications.

Notices are often posted inside the doors of the shift change room and the staff room. These notices contain information applicable to the general nursing staff. At times, they contain important information pertinent to the provision of healthcare, while other times, they advertise social activities and educational opportunities. Nevertheless, they are integral to complete information sharing process in the unit.

***Verbal media*:** Verbal media in the ward represents an ephemeral common information space constructed by co-present participants to affect the information flow. Participants therefore communicate synchronously to negotiate and interpret the information in transit. While the outgoing nurse is speaking – placing audio information in the CIS – the incoming nurse will simultaneously interpret and often transpose this information to a different media in her PIS, typically a paper-based medium such as a note-sheet or an annotated patient care summary.

All outgoing nurses working in this ward must verbally report to the charge nurse of the shift unless the latter is too busy to receive reports. In that case, outgoing nurses will write a brief report on the charge board, which is intended to be used by charge nurses only, as a contingent alternative. This charge reporting is important so that the charge nurse on duty will acquire information of each patient and an overall knowledge of the ward [3,10]. As a result, the outgoing charge nurse can then hand the information over to the incoming charge nurse.

While verbal reporting between nurses working in consecutive shifts is not mandatory, our observations reveal that this reporting medium is discretionarily used, especially when the outgoing nurse is too busy to update the whiteboard inside the shift change room. Some nurses give a verbal report even after they have updated the whiteboard to make sure that the next shift nurse interprets the displayed information as intended. Most nurses, however, do one or the other, unless the incoming nurse specifically asks for a verbal report as well.

Information Content and Function Types

We examined the physical artifacts, specifically the personal notes, which we collected during our study to find out what content and function types of information are used. We found many similarities in the kinds of information extracted from the various information media. These information types help answer the questions about information content and purpose. The following information types that we have identified may not be exhaustive, and a given piece of information may fall into one or more of these categories.

Demographics list a patient's name, age, gender, room/bed number and caring physician. Our interviewed participants

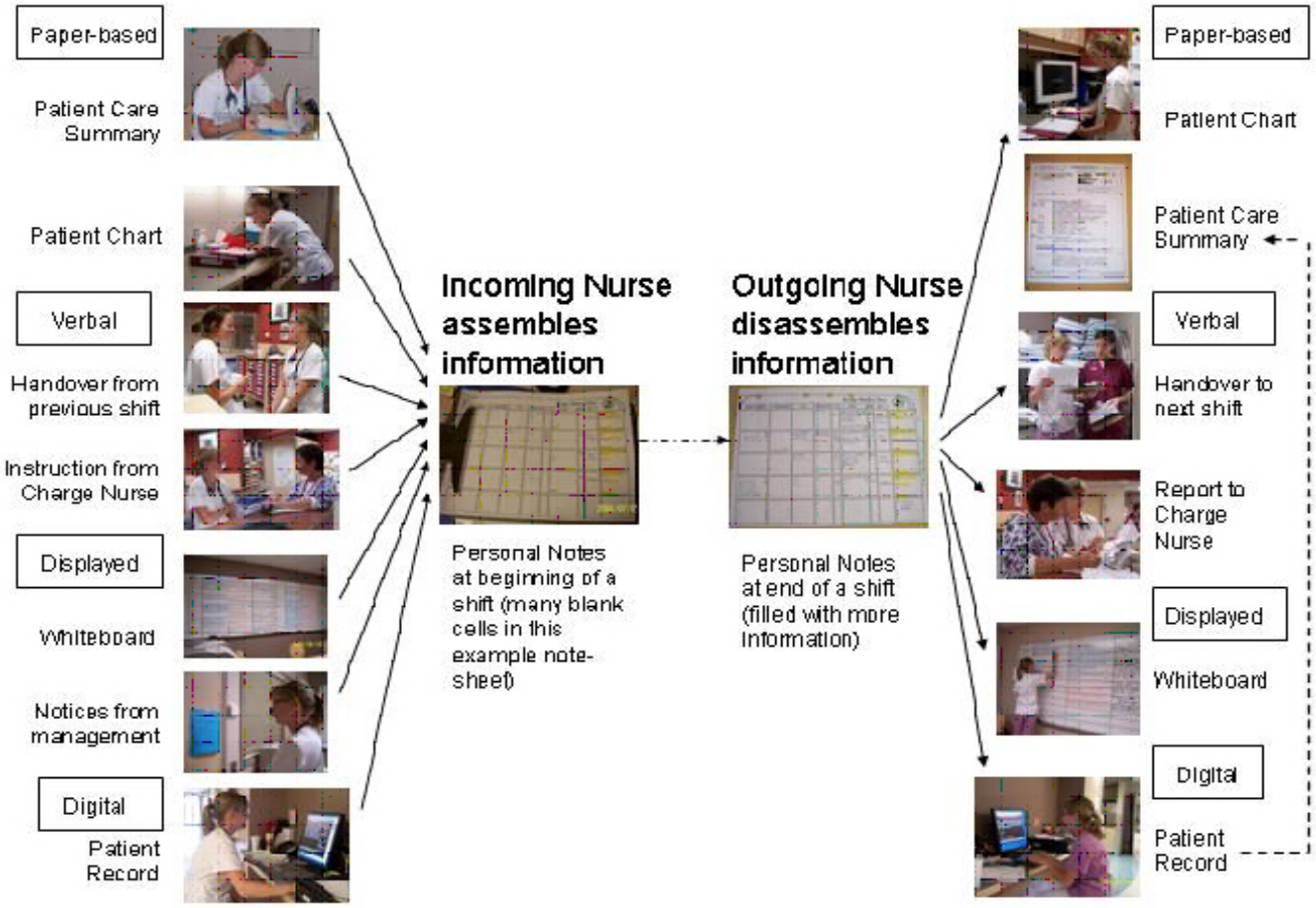

Figure 2: Information assembly and information disassembly activities performed in parallel during shift change

who did not use separate personal notes explained that transposing their patients' demographic information into the note sheet was too labour-intensive to do manually.

Historical Information includes a patient's past medical information such as initial diagnosis, treatments performed and their illness trajectories.

Reminders and To-Dos serve as *aide memoires* such that action has to be taken by the participant. These may appear singly or in groups and are usually attached with a temporal marker, for instance indicating that a task needs to be performed at certain time or time interval.

Alerts are often intrinsically historical information that directly affects the well-being, and more importantly the survival of a patient. Prominent examples of this include specific allergies, isolation status and resuscitation level such as DNR (do not resuscitate).

Prompts are personally created information place-holders. These come with a variety of information buckets (e.g., text lines and checkboxes) that require participants to fill in information while at the same time serving as memory triggers. They are also used as status indicators showing if a task has been accomplished.

Scheduling is information that participants must seek to arrange with third parties such as physiotherapists, occupational therapists or social workers for the patients. This is often less time-sensitive than reminders and to-dos.

Reporting is gathered during patient assessment and needs to be reported to the next shift or other pertinent personnel. For example, changes in treatment progress must be reported to the responsible physician and any variation in a patient's well-being must also be reported to the next caring nurse.

Types of Information Spaces

During our study we observed the use of both common information spaces (CISs) and personal information spaces (PISs). The common information spaces are well aligned with Schmidt and Bannon's definition – "encompasses the artifacts that are accessible to a cooperative ensemble *as well as* the meaning attributed to these artifacts by the actors" [14]. A personal information space differs only in that the information space is owned and manipulated by a single individual.

Common Information Spaces

We observed that cross-shift communication between nurses and inter-disciplinary communication in W21C is predominately asynchronous and largely conducted by distributed collaborators. By 'distributed', we mean collaborators who are temporally and/or spatially separated making face-to-face communication unlikely. For instance, nurses of consecutive shifts do not usually meet to communicate, doctors are not often in the ward but when they are they write down instructions to nurses in a patient chart, and ancillary professionals operate similarly to doctors in that they also write on the patient chart. These CISs constructed by this temporally distributed team are characterized by a high degree of closure in that people do not dispute entries. However, the medical data recorded remains dynamic in that their meaning may be continually changed by additions and re-articulated comments. This observation agrees with Jirotka et al.'s discussion [12]. These types of CISs were externalized through some kind of coordinative physical artifacts, e.g., a patient chart and the electronic health record. The information set, in particular medical assessment and treatment information, is constantly being generated by a wide range of collaborators including doctors, ancillary professionals and outgoing nurses during their shifts. This information set plays the crucial role of input for the next shift as well as for the other health professionals, enabling continuing patient care. Collaborators achieve the information flow by packaging and placing the information (with intended meaning) in appropriate CISs so that the information can be shared with concerned personnel. To do this, outgoing staff often rely on some form of personal artifacts which will be discussed in more detail in the next subsection.

Although less frequent, nurses across shifts are sometimes co-present to communicate during shift change. The CISs are then often constructed through a combination of verbal and gestural communication. For example, while Lily explained a patient's condition, she gestured to a location on her own body to indicate where the patient had a wound during the verbal report to her next shift. Such a verbal CIS is highly open and malleable for immediate clarification when ephemeral information is misinterpreted.

Interviews with our participants indicated that communication may break down when the interpreted meaning deviates from the intended one, especially when clarification is not possible. Consequently, incidents such as an inappropriate treatment may be performed as a result.

The CISs that we have observed are jointly constructed by participants, making use of coordinating artifacts and the attached meanings derived from a diversity of information sources. These CISs are maintained and enriched continually with the latest medical information that is important to ensure smooth and continued provision of healthcare services in the ward. We now turn our attention to the PISs that play a crucial role in bridging between work in progress and the CIS of pre-shift and post-shift.

Personal Information Space

We observed personal information spaces (PISs) being actively constructed by incoming nurses at the beginning of their shifts. As information was gathered from the CISs (left of Figure 2) it was first interpreted and then transposed to the nurses' own PIS. These PISs typically involved the use of a physical artifact such as a note sheet. In practice, individuals use a combination of physical artifacts and mental capacity as the constituents of their PISs. For example, 7% of our participants used the previous shift report by committing it to memory. The PIS is constructed at the beginning of the shift then during the shift it is dynamically re-configured with additions and annotations and is actively used to facilitate the performance of tasks during a shift (Figure 2 middle). At the end of a shift, information gathered during a shift and stored in the PIS (including both physical artifacts and mental capacity) will be contextualized and organized for dispensing into appropriate CISs (right of Figure 2). As such, the personal notes are found to serve as the primary coordinating artifacts to facilitate tasks performance during a shift.

We examined the physical artifacts collected in our study. We found that they are largely composed of a variety of information types in terms of content and function. The coordinating physical artifacts created and used by our participants are also found to be highly individualized with generous use of visual attributes. A wide range of visually attentive objects and features are used to make the information carried by these objects and features to stand out. Pre-attentive features such as text orientation, spatial clustering, added marks, unique symbols, color-coding and 2D spatial position [17] were generously used to represent different content and function types of information. They also employed physical attributes such as staggered notches which were cut off the bottom-right corner of their stack of patient care summaries so that each patient's record stands out for easy retrieval (Figure 3). When nurses created their own personal artifacts all notes were written and visualized on a single page of artifacts.

Moreover, our observations and interviews both indicated that the nurses have their own spatial arrangement for different types of information when creating their personal

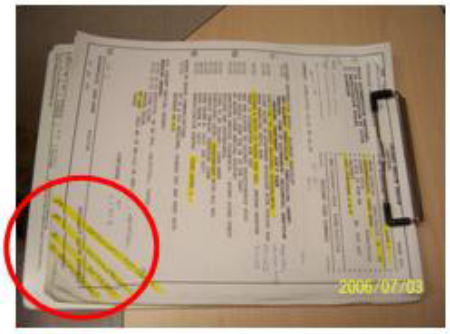

Figure 3: Patient care summary with staggered notches cut at the bottom right corners.

artifacts. Specifically all participants with separate personal notes and almost 90% of participants who annotated patient care summaries have a habitual spatial organization and layout of information. The spatial plan serves as a spatial memory trigger that helps when they look for a particular kind of information. This is particularly important when they are carrying out time-critical activities.

Types of Information Processes

We observed that information flow across shifts was dominated by two processes that take place in parallel: information assembly by incoming nurses (Figure 2, left) and information disassembly by outgoing nurses (Figure 2, right). Another significant information process we observed is the temporal coordination between information assembly and disassembly.

Information Assembly

We define information assembly as a collective process involving a series of activities for seeking information from a multitude of spatially-distributed information sources. (Figure 2, left). An incoming nurse starts a shift by physically moving around to seek information from information sources in different locations. To illustrate, an incoming nurse often starts inside the shift change room to extract information from the patient care summaries and the whiteboard. She then moves to the nursing station where patient charts and electronic health record (EHR) may be accessed. Verbal instructions/reports from the charge nurse/previous shift nurse may also be obtained here or other locations inside the ward. Afterwards, she goes to the ward wing where her patients stay. She may then retrieve the EHRs from the computers located along the corridors (Figure 1). In addition to the information sources being spatially separated, most of them are mobile. Thus they may at a given moment have been temporarily removed from their designated location by other nurses or other health professionals. Such mobility may accentuate the complexity of the information assembly process when the information seeker needs to first track down the location of the information sources before she can seek and assemble information from the sources. This process is further complicated if the incoming nurse needs to assemble information from personnel not included in Figure 2, e.g., physicians and ancillary professionals. This information assembly process may be regarded as completed when enough information has been gathered for the shift work. Yet, in practice, the completion of information assembly process may not be as crisp depending on if there are pressing issues that require the nurse's immediate attention.

Information Disassembly

Information disassembly is primarily the reverse process to information assembly. To disassemble the collected information gathered during their shift, outgoing nurses have to move spatially to each information artifact (Figure 2, right). They organize their own notes, predominately mentally, and then disseminate the information to appropriate information artifacts in a way that they believe will be understood by their intended readers. We found that outgoing nurses rely heavily on the contents placed in their personal notes when disassembling the collected information back to the information repositories (these are the information sources during information assembly). Current routines at the end of a shift include updating the patient chart, updating the electronic health record, posting a shift report on the large whiteboard as well as verbally reporting to the charge nurse. Unlike the information assembly activities, some information disassembly activities may be performed well before the end of a shift, especially when no changes are expected in a patient's condition or treatment. The completion of the information disassembly process is usually more clear-cut, often marked by the nurse disposing of their more ephemeral personal artifacts.

Temporal Coordination

In our observations, we found no specific order by which the information assembly and disassembly activities were performed. While the incoming nurses typically start by seeking information from the patient care summaries and the shift report on the whiteboard, if available, there is no specific order in which they seek information from other information sources. Similarly, the outgoing nurses described that the order of performing the information disassembly activities largely depended on the preference of individual nurses, their workload and the availability of concerned personnel. To achieve the information flow across shifts smoothly, information assembly and information disassembly are not two separate standalone processes. Rather, the process of information assembly is temporally dependent on the information disassembly process and they have to be temporally coordinated within a brief time frame during shift change [13]. Otherwise, the information flow may be broken, at least temporarily, and other contingent practices which usually require more time and extra effort to be undertaken. For example, an incoming nurse needs to find out what has taken place in the previous shift(s) and such information should be displayed on the large whiteboards inside the shift change room. However, if the outgoing nurse did not update the board in time, the incoming nurse will then have to look for the outgoing nurse and ask for a verbal report. However, if the outgoing nurse cannot be reached, the incoming nurse will have to either ask the charge nurse, or look up the electronic health record which may contain the required information. From our interviews, the participants expressed that their knowledge and familiarity with their colleagues' practices helped coordinate the information seeking process. For example, Nancy knows that the nurse working the previous shift often writes a very brief shift report on the whiteboard and prefers a verbal report. She then always expects a detailed shift report when Greg 'hands over' the patients to

her. This finding agrees with the 'biographical familiarity' identified in [12].

DESIGN IMPLICATIONS

Our study found that information flow during shift change involves a rich set of information, media, and locations. Computer technology may have a good potential to improve the situation by replacing and/or supplementing some existing technology in a manner that may offer a more coherent and comprehensive information ensemble. Although it may be premature at this point to design technology to support the practical work during shift change, the findings from this study offer implications for the design of technologies for enhancing the information flow in the specific medical setting.

CIS and PIS Interaction: Understanding the nuanced interaction between the common information spaces and the personal information space can help inform the design for preserving and managing their use and ownership. It is important to understand the characteristics of the CISs and the roles they play in the information flow. As some CISs are constructed by a wide range of personnel, we must also consider the use of artifacts if these spaces are to be augmented with technological support. Similarly, we need to consider how PISs can be supported with technology without requiring extra effort from users to maintain both information spaces.

Consistency of Terminology: Communication can break down when the interpreted meaning of information inscribed in the information artifacts deviates from the intended one. Since one of the causes may be the use of inconsistent notations and language, use of agreed upon terminology within supporting technology may reduce miscommunication.

Customizability of PISs: As all the nurses create and customize some form of personal notes which then serve as the primary coordinating artifacts for facilitating task performance during a shift, these personal artifacts justify a closer examination. For instance, any technology considered should allow nurses to customize their personal information space and to include interaction mechanisms. For example, the technology could provide a choice of visual elements that support pre-attentive processing, and allow positioning of information by using such things as spatial clustering or orientation. Also, since rapid indexing and retrieving of information is currently manifested in all observed PISs, some facility for this is another important feature to include in technological support. For instance, the personal information space could be completely visible or incorporate some intuitive indexing for easy retrieval of patient information.

Support Redundancy: With the multiplicity of information artifacts involved during shift change, it is not surprising that redundancy may exist. However, such redundancy may perform some type of backup function and the complementary artifacts may provide for more comprehensive information. We should therefore investigate if and how such redundancy should be eliminated [7] and how the rich information provided through complementary artifacts can be upheld.

Introduction of Technology: Information assembly and disassembly processes are complicated due to the varied information sources and their spatial distribution. At first glance, individual information sources may be replaced by innovative computational devices to enhance the efficiency during shift change with minimal impact on current work practices. For instance, large digital boards may replace the existing whiteboards. The mobile and dynamic nature of nursing work also appears a good candidate for mobile technology so that nurses may remain at the point of care while retrieving and documenting pertinent records. Timely and up-to-date patient assessment information would then be available for incoming nurses who then need not expend extra effort to seek this information. Instead, they can spend more time with their patients. In fact, the use of portable devices in clinical settings has been found to reduce the time spent in documentation and the patient outcomes and safety are also improved, while communication errors and omissions are reduced with the employment of point-of-care documentation [15]. Thus we should look into the possibility of introducing mobile technology at the ward. We may also consider context-aware technology by embedding the information processing devices into the environment more naturally and casually as a means to ease the mobility issues [2].

It is intimidating to design technologies to encompass the richness of existing practices of information flow in information-critical medical settings. Yet, we envision nurses being able to acquire information they deem important from the multitude of information spaces and visualize the collected information in their desired representation alongside a range of intended interaction mechanisms without requiring nurses to mundanely seek for and manipulate the required information.

CONCLUSION AND FUTURE WORK

We have conducted an observational study at W21C to investigate how information flow takes place during shift change. This study is one step towards our goal: to design and develop a technology prototype that will appropriately support the practical activities and actions that take place during shift change.

We have identified a rich set of spatially-distributed information sources with which nurses are required to interact for both assembling and disassembling information. These processes of information assembly by incoming nurses and information disassembly by outgoing nurses during shift change have been shown to be a complex task. It is complex because (1) it involves a variety of media: paper-based, verbal, displayed and digital sources; (2) these media sources are distributed over spatial locations such as

the shift change room, the nursing station, the computer terminals and the four wings in the ward; and (3) the information assembly and disassembly activities take place almost in parallel within a brief time period. Spatial movement across different information media and subtle temporal coordination are therefore required to ensure that information is available at the right place and at the right time.

We also observed participants spatially arrange information on the personal artifacts and how such arrangement compliments the information types identified to facilitate the manipulation of their PIS. Our results, confirmed by follow-up interviews, showed that 39 out of 40 participants have a regular practice of spatial organization and layout of information to help them locate information in their PIS.

While the coordinating artifacts readily emerge, the specifics of the information exchange activities undertaken could benefit from considerable further study in terms of how exactly the information is shared and how effective the current processes are for supporting the collaborative work. This includes understanding what information is placed in the common information spaces, how information is packaged or contextualized so that the intended meaning will be perceived, how information in the common information spaces is manipulated, interpreted, negotiated and transposed to the personal information space, how the information types used in a PIS relate to their spatial positioning, how the local mobility required for information flow among the multitude of information spaces unfolds and how the reverse flow of information takes place during information disassembly. In addition, the problems nurses face during the information flow and how they cope with the breakdown of information flow are of interest for further investigation.

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REFERENCES

1. Bannon, L. and Bodker, S. (1997). Constructing Common Information Spaces. In *Proceedings of the ECSCW, 1997*, Kluwer, pp. 81-96.
2. Bardram, J. (2004). Applications of Context-Aware Computing in Hospital Work – Examples and Design Principles. In *Proceedings of the 2004 ACM Symposium on Applied Computing*, pp. 1574-1579.
3. Bardram, J. and Bossen, C. (2005). A Web of Coordinative Artifacts: Collaborative Work at a Hospital Ward. In *Proceedings of the 2005 International ACM SIGGROUP Conference on Supporting Group Work*, pp. 168-176.
4. Bardram, J. and Bossen, C. (2005). Mobility Work: The Spatial Dimension of Collaboration at a Hospital. In *Computer Supported Cooperative Work*, 14(2), pp. 131-160.
5. Baylis, B. (2005). Ward of the 21st Century. In the IASTED International Conference on Telehealth, 2005 appeared in http://www.iasted.org/conferences/2005/banff/th-invitedspeaker4.htm.
6. Bossen, C. (2002). The Parameters of Common Information Spaces: the Heterogeneity of Cooperative Work at a Hospital Ward. In *Proceedings of the Conference on Computer-Supported Cooperative Work,* pp. 176-185.
7. Cabitza, F., Sarini, M., Simone, C. and Telaro, M. (2005). When Once Is Not Enough: The Role of Redundancy in a Hospital Ward Setting. In *Proceedings of the 2005 International ACM SIGGROUP Conference on Supporting Group Work*, pp. 158-167.
8. Currie, J. (2002). Improving the Efficiency of Patient Handover. In *Emergency Nurse* 10(3), June 2002.
9. Goodwin, C. and Goodwin, M.H. Formulating Planes: Seeing as a Situated Activity. In Distributed Cognition in the Workplace, eds. D. Middleton and Y. Engestrom. Cambridge, UK: Cambridge University Press.
10. Harper, R. and Hughes, J. (). What a f-ing system! Send 'em all to the same place and then expect us to stop 'em hitting: Making Technology Work in Air Traffic Control. In Technology in Working Order, ed. G. Bulton, Routledge, London.
11. http://www.safetyandquality.org/clinhovrlitrev.pdf Clinical Handover and Patient Safety Literature Review Report, March 2005.
12. Jirotka, M., Procter, R., Hartswood, M., Slack, R., simpson, A., Coopmans, C., Hinds, C. and Voss, A. (2005). Collaboration and Trust in Healthcare Innovation: The eDiaMoND Case Study. In Journal of CSCW, Vol. 14, No. 4, 2005, pp. 369-398.
13. McGrath, J. (1990). Time Matters in Groups. In J. Galegher, R. Kraut and C. Edigo (eds.): Intellectual Teamwork: Social and Technological Foundation of Cooperative Work. New Jersey: Lawrence Erebaum Associates, pp. 23-61.
14. Schmidt, K. and Bannon, L. (1992). Taking CSCW Seriously: Supporting Articulation Work. In *Computer Supported Cooperative Work (CSCW): An International Journal*, Vol. 1, No. 1, 1992, pp. 7-40.
15. Strople, B.and Ottani, P. (2006). Can Technology Improve Intershift Report? What the Research Reveals. Journal of Professional Nursing, 22(3), 2006, pp. 197-204.
16. Schmidt, K. and Simone, C. (1996). Coordination Mechanisms: Towards a Conceptual Foundation of CSCW Systems Design. In *Computer Supported Coopertive Work: The Journal of Collaborative Computing 5*, pp. 155-200.
17. Ware, C. (2004). Information Visualizations: Perception for Design, 2nd Edition, Morgan Kaufman.